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TEMPERATURE OPTIMA FOR HUMAN ENERGY

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As a step toward the more exact determination of climatic optima for human species I have made a study of temperature in relation to (1) the death-rate, (2) the amount of work done by piece workers in factories, and (3) the strength of individuals as measured by the dynamometer. Although the matter is still in its early stages, the results show that the field of investigation is marvelously rich, and that only the surface has yet been scratched.

(1) *The death-rate* is an excellent means of determining climatic optima. In most parts of the United States two maxima of deaths occur under widely different climatic conditions, one in winter and one in summer. Between the maxima come two minima both of which appear to be associated with essentially the same climatic conditions whether they occur in spring or fall. At first sight this may not be obvious since in the northeastern United States one minimum generally comes in June when the mean temperature is 65° to 70°F and the other in October when the temperature is 10° or 15° lower. Conditions of health, however, obviously lag behind the climatic conditions with which they are connected. An interval must elapse between the time when people fall sick and the time when they die. If allowance is made for this, the true optima would be found in May and September, two months which have about the same temperature.

Since it is difficult to determine the exact amount of lag between given climatic conditions and the death-rate which they determine another method may be employed for determining the optimum temperature. The months may be arranged according to their temperature without regard to the seasons of the year. If the figures thus obtained are smoothed, a lag in one direction is neutralized by a lag in the other. The method is illustrated in table 1.

A glance at the last column shows that deaths in New York are numerous at low temperatures. They decline quite steadily until an optimum is reached when the mean outside temperature is about 65° F. Then they increase once more. The true optimum, however, is a trifle lower than 65°. Many people leave New York in summer and some of them die, but these deaths do not appear in the city records. Consequently the recorded deaths in July and August and to a less degree in September and June are below the number actually occurring in the city's

TABLE 1
MEAN TEMPERATURE AND DEATHS IN NEW YORK CITY, 1900-1911

MONTH	MEAN TEMPERATURE		DEATHS PER DAY	
	Actual	Smoothed*	Actual	Smoothed*
January.....	30.2	(30.2)	256	(256)
February.....	30.7	31.5	266	257
December.....	34.4	34.3	238	253
March.....	37.5	38.4	270	248
November.....	44.0	43.4	215	242
April.....	48.1	48.9	267	240
October.....	55.5	54.6	210	231
May.....	59.3	60.2	239	227
September.....	66.5	65.2	218	225
June.....	68.5	68.9	224	226
August.....	72.2	71.6	236	241
July.....	73.5	(73.5)	266	(266)

* The smoothing is done by the formula $\frac{a + 2b + c}{4} = b$

entire population. This alters the apparent optimum, but not more than a degree or two, for relatively few people are away in September and June. Therefore, on the basis of the death-rate the optimum temperature in New York City appears to be 63° or 64°F.

Table 2 shows the optimum temperature for three groups of American cities and for a group of foreign countries, all being reckoned in the same way as New York.

Aside from New Orleans the optima range from 58° at San Francisco to 70° at St. Louis. Local differences arise from humidity, epidemics, the season at which vacations are taken, and other minor causes. Nevertheless the averages for the four groups differ surprisingly little, the range being only from 62.7° to 65.8°. This seems to indicate that whether we are dealing with northwestern Europe, the northern, central, or southern United States, or an Asiatic country such as Japan, deaths are most numerous at about the same temperature. When allowance is made for the effect of summer vacations in the American cities, it appears that the optimum is probably about 63° F. Since we are dealing with the mean temperature of day and night, such an optimum means that man is physically at his best when the temperature rises to about 70° at noon, but not when it stays all day at that level.

(2) *Daily work.* People's daily work is perhaps the best test of their physical condition. During the past few years I have collected statistics of the work of piece-workers in factories from Connecticut to Florida. A comparison of their work with the mean out-of-door temperature gives the results shown in table 3.

TABLE 2

OPTIMUM TEMPERATURE ON THE BASIS OF THE DEATH RATE

PLACE	YEARS	OPTIMUM TEMPERATURE
Group I. <i>Northern cities of the United States.</i>		
Boston.....	1900-1911	66°
Buffalo.....	1900-1914	61°
Chicago.....	1900-1911	67°
Cleveland.....	(17 years)	64°
New York.....	1900-1911	65°
Philadelphia.....	1900-1914	67°
Seattle.....	1900-1914	62°
Average.....		64.6°
Group II. <i>Central cities of the United States.</i>		
Baltimore.....	1900-1911	63°
Cincinnati.....	1900-1911	69°
Pittsburg.....	1900-1914	67°
St. Louis.....	1900-1914	70°
San Francisco.....	1900-1914	58°
Washington.....	1900-1914	68°
Average.....		65.8°
Group III. <i>Southern cities of the United States.</i>		
Atlanta.....	1900-1911	64°
Birmingham.....	1900-1914	
Los Angeles.....	1900-1911	68°
Memphis.....	1900-1914	60°
New Orleans*.....	1900-1911	81°
Average.....		65.0°
Group IV. <i>Foreign countries.</i>		
Belgium*.....	1861-1910	above 63°
Finland*.....	1900-1912	above 61°
Germany.....	1912	64°
Japan.....	1899-1908	64°
Stockholm.....	1906-1914	60°
Average.....		62.7
Grand average.....		64.5

* Belgium and Finland are so cool in summer that no entire month has a mean temperature as high as the optimum. New Orleans is peculiar because so large a part of the population moves away in summer. Hence these places are omitted in computing the averages.

TABLE 3

OPTIMUM TEMPERATURE IN FACTORIES

PLACE	NUMBER OF PEOPLE	OPTIMUM TEMPERATURE
1. { Connecticut.....	300 men	59°
	200 women	60°
2. Pittsburg.....	8800 men and women	63°
3. Tampa.....	1200 men	67°
Average.....		63°

This seems to suggest a slight rise in the optimum as one goes from cooler to warmer climates, but it is doubtful whether the inference is justified. The mean temperature of Pittsburgh averages only 3° F. warmer than that of southern Connecticut, and it is not likely that so small a difference could cause an equally great difference in the optimum. The relatively high optimum in Florida may arise partly from the fact that the people whose work was tested at Tampa were Cubans coming from a climate even warmer than that of Florida. Little weight can be placed on such a conclusion, however, because the Cubans were engaged in cigar making and in this work high temperature, especially when accompanied by moisture, makes the tobacco pliable and hence enables people to work rapidly. Thus the apparent optimum is raised a little. Moreover, in the present study no account is taken of the effect of humidity upon human energy. This factor is of much importance and probably accounts for a large part of the variation in the apparent temperature optimum from place to place.

(3) *Strength tests.* In Denmark Lehmann and Pedersen some years ago carried on a series of tests of the strength of school children at all seasons. When due allowance is made for the normal growth of the children it appears that they were strongest when the temperature averaged not far from 59°. For 16 months during 1915 and 1916 the writer was fortunate enough to secure the cooperation of the teachers at Hampton Institute, Virginia. The strength of 11 negro students was tested daily with a dynamometer. The young men were strongest at an average temperature of 61°. An equal number of young women were tested in the same way, but they were working under abnormal conditions in a hot, steamy laundry. Accordingly their apparent optimum was at an average outside temperature of only 52°.

Summing up the results of these various methods it appears that the death-rate of millions of individuals indicates an optimum at 63° or 64°. The factory work of thousands of people points to the same temperature as the best for human activity. Tests of the strength of individuals suggest a slightly lower optimum, at about 60°, but the number of cases is small. The investigations of Rosenau and Thompson also indicate an optimum at 62° or 63°. Since Finns, Japanese, Germans, and Americans all show essentially the same response, it seems probable that the optimum temperature for physical activity among people in all sorts of climates does not vary far from 63° F. Even a long residence in a given climate apparently has little effect in causing people to become adjusted to their environment. The Finn still seems to find his climate always too cool, while the Cuban finds his too warm.

It appears as if climatic environment were able to cause changes in pigmentation and bodily form more easily than in the more direct physiological conditions which determine the relation of the organism to temperature.

There is probably, however, a slight difference in races, as appears from a comparison of the deaths among colored and white people in the twelve American cities where colored people are most numerous. Unfortunately the figures for the two races have been published separately only since 1912, and only the years 1912-1914 are available. The results are given in table 4.

TABLE 4

OPTIMUM TEMPERATURE AMONG WHITE AND COLORED PEOPLE DURING THE YEARS 1912-1914 ON THE BASIS OF THE DEATH RATE

PLACE	WHITE	COLD	PLACE	WHITE	COLD	PLACE	WHITE	COLD
I. Northern cities			II. Central cities			III. Southern cities		
New York	68.5	71.4	Baltimore	60.4	69.2	Atlanta	59.2	72.4*
Chicago	65.5	69.4	Louisville	68.0	74.5	Birmingham	73.3	72.2
Philadelphia	68.0	74.0	St. Louis	70.8	74.9	Memphis	68.2	76.8
	—	—	Washington	65.3	69.2	Richmond	66.4	66.4
Average	67.3	71.8		—	—	Average	66.8	72.0
			Average	66.6	72.0			

Weighted Grand Average: White 67.5, Colored 71.6

* This figure is doubtful. A much more pronounced minimum of deaths occurred at a temperature of 44°. This apparently means that a good many colored people come to Atlanta in the summer and go away in the winter.

Because of peculiar weather conditions, epidemics, or other causes the optimum during the years 1912-1914 was 2° or 3° higher than during the longer series of years indicated in a preceding table. Such differences are inevitable and need not here concern us. The important point of the present table is that as a rule the negroes seem to be at their best at a temperature 4° or 5° higher than that which is best for white people. This, however, is insignificant compared with the difference of 40° between the mean temperature of the Baltic home in which the white race probably developed and the African home of the negroes. Moreover, the average optimum temperature in northern, middle, and southern cities is almost identical. There is not the slightest hint that either the whites or the colored people by residing in the north or the south have become adjusted to a particular temperature. So far as these facts go, therefore, they suggest that man's adaptation to temperature is so deep seated and of such remote origin that it changes very slowly. Untold thousands of years of the contrasted environments of northwestern Europe and central Africa appear to have produced a

permanent racial difference of no more than 5° and possibly less, while the short time that the American people have been in their present surroundings appears to have caused no differentiation.

In spite of the apparent fixity of the optimum there appears to be a marked adaptation to other conditions. This is illustrated in table 5, where the smoothed death-rate for New York and Los Angeles at intervals of 2.5° is given in percentages of the average per year. The table brings out the far greater range of temperature at New York than at Los Angeles. It also brings out the curious fact that while the worst

TABLE 5
DEATHS IN VARIABLE AND UNIFORM CLIMATES

MEAN TEMPERA- TURE F.	NEW YORK CITY	BALTIMORE	JAPAN	SAN FRANCISCO	LOS ANGELES
30.0°.....	107.0	.....	.....	.....	.....
32.5°.....	106.5	109.5	.....	.....	.....
35.0°.....	105.5	106.0	.....	.....	.....
37.5°.....	104.5	104.5	107.0	.....	.....
40.0°.....	103.0	101.5	102.0	.....	.....
42.5°.....	102.0	100.0	100.5	.....	.....
45.0°.....	101.0	98.5	98.5	.....	.....
47.5°.....	100.5	97.5	97.5	.....	.....
50.0°.....	99.5	96.5	96.5	117	.....
52.5°.....	98.5	95.5	96.0	108	117
55.0°.....	97.5	94.0	95.0	102	113.0
57.5°.....	96.5	92.5	94.0	90	103.5
60.0°.....	95.5	91.0	93.0	91	97.0
62.5°.....	95.0	90.0	91.5	.....	93.0
65.0°.....	94.5	89.5	92.0	.....	91
67.5°.....	95.5	90.0	95.0	.....	86?
70.0°.....	98.0	91.0	98.0	.....	92
72.5°.....	106.0	94.5	102.0	.....	.....
75.0°.....	.....	102.0	105.5	.....	.....
77.5°.....	.....	118.0	109.5	.....	.....
80.0°.....	.....	.....	115	.....	.....
Range from highest to lowest.....	11.5	20	23.5	27	31

months at New York have only 107 deaths where the average is 100 and the best only about 94, the range at Los Angeles is from 117 to 86. With less than half as great a range of temperature Los Angeles has two and one-half times as great a variation in the death-rate. The health seekers who visit southern California in the winter account for a small part of this difference, but by no means for all of it. At the range of temperature prevailing in Los Angeles the New York death-rate varies only about 4% or less, while that of Los Angeles varies 31%. If the influx of health seekers explained the matter they would have to increase the population of Los Angeles by more than a quarter of its normal propor-

tions every year. Moreover, San Francisco where the number of health seekers is comparatively small, shows a contrast from season to season practically the same as at Los Angeles. I do not feel sure how to explain this. It looks, however, as if the variable climate of the east causes people to become comparatively resistant to changes of temperature, while the uniform climate of the Pacific coast although delightful in itself, causes people to lose the power of resistance and hence to succumb quickly under adverse conditions. In table 5 localities are arranged according to the variability of their climates. The range between the highest and lowest death rates for the year is least in New York where the climate is most variable, and greatest in Los Angeles where the climate is most uniform.

THE PARALLAX OF THE PLANETARY NEBULA N. G. C. 7662

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The first results for the determination of stellar parallaxes obtained with the 80-foot focus arrangement of the 60-inch reflector were communicated to these PROCEEDINGS about two years ago.¹ The promising outcome of that investigation was fully confirmed by later results; the small probable error and the apparent absence of large systematic errors showed the desirability of extending the work to some of the nebulae. The parallaxes available for these interesting bodies are as yet extremely rare and the few existing results are far from trustworthy. For instance, about half a dozen determinations for the large spiral nebula in Andromeda have been published, the results ranging from $-0''.32 \pm 0''.12$ to $+0''.171 \pm 0''.051^2$.

Six nebulae were accordingly added to the Mount Wilson parallax program. In most cases the necessary exposure times are considerable and for several fields the work cannot be finished for some time. The planetary nebula N.G.C. 7662 (= H IV 18 Andromedae), which has a sharp stellar nucleus, gives good measurable images in a 25 minutes exposure (see Plate). Sixteen exposures were secured, the details of which are given in table 1. The successive columns contain the plate number, the date, the hour angle in degrees, the initials of the observer (H = Hoge, VM = van Maanen), the quality of the plates, the parallax-factor, the factor for annual proper motion, and finally some remarks.